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PRACTICAL WORK IN SCIENCE TEACHING

Most of us, and particularly those who are interested in teaching some one special branch of learning, are likely to forget that the great aim of all educational processes is to uplift and benefit humanity; and are likely to hold an exaggerated opinion of the value of our special branch in the general scheme of education. This view is perhaps natural and justifiable, since without it enthusiasm could not exist and teaching would lose much of its pleasure. The breaking away from the older forms of stereotyped abstract forms of education where a somewhat narrow point of view was so long held came in response to a demand that men be free to study *all* forms of natural phenomena living or lifeless and to draw therefrom spiritual inspiration or bodily sustenance as might be available. This movement was greatly aided and hastened by the fact that the conclusions drawn from the study of natural phenomena were of direct use in industry. They were to a large extent, and are still, the result of industrial demands and in so far as they answer these demands they have been of tremendous assistance in affording better support to human life, which after all is the great central problem. In later years this movement has been further strengthened by the discovery that the study of natural phenomena led to a certain form of mental training that afforded a powerful means of attacking abstract problems. The term "scientific method" has come to mean a somewhat definite way of approaching the solution of all problems as opposed to older and so-called empirical methods. And at the same time it has appeared that this same study of things mundane, if properly conducted, actually bestowed upon the student thereof a certain amount of general or liberal training, greater perhaps than the adherents of the old school would admit, and less perhaps than the more ardent advocates of the new methods usually claim.

From time to time we are warned by educational reformers that education to be effective must be kept close to the ground, and must draw its inspiration from the life of the community it tries to serve. Education *is* life and not merely preparation for life, and all forms of educational effort that ultimately survive will be those that in some way throw light on the current problems of existence. That this is so can not be doubted by any one that has noted the changed point of view of many of the older forms of educational effort. History is no longer a mere chronological record of kings and battles, but is rapidly being vitalized into a lesson for the future by *analyzing* the records of the past; and the classics themselves will not reach their highest development and usefulness till they are interpreted by their sponsors, not as the dry and dusty records of past ages, but as vital lessons in the mainsprings of human thought and action. In no document that I know of has this point of view been so clearly and concisely expressed as in the Morrill act, the foundation of our state colleges of agriculture and the mechanic arts, which states that "the leading object of these colleges shall be, without excluding other scientific and classical studies and including military tactics, to teach such branches of learning as are related to agriculture and the mechanic arts in such manner as the legislatures of the states may respectively prescribe in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life." Truly this document may well be called our declaration of educational independence and is worthy of the careful perusal of every teacher.

In the general truth and expediency of these principles most of us are fully agreed. In fact in these days when industry is the idol, not only of our own, but of all other progressive nations, they hardly admit of argument. The teaching of so-called practical courses holds an assured place. But apparently the influence of heredity runs strong in our veins, and no sooner do we lift the study of a practical subject from the realm of empiricism to a scientific basis, than we begin to codify, classify and tabulate its scientific basis, mathematically, chemically and physically. This is a natural and correct thing to do, as it is

the most accurate and most convenient way to express and record the principles of the phenomena that we have studied. It is also the best way in which these principles can be expressed to be of service in future investigations and to scientific men generally. But in our enthusiasm over our specialty we are prone to forget some of the foregoing principles. We are likely to forget that men come in different sizes and grow to different heights; we may forget that the requirements and *capabilities* of the scientist and the plain every-day man are vastly different in *character,* though perhaps not so different in *degree.* As a matter of fact, our public school system is founded on the supposition that all men are born equal in opportunity as well as in an intellectual sense, which is far from being a reality. The result is that most of our educational processes tend to grow away from industry and the soil and the preparation of those that are to labor in the more humble callings and to take cognizance only of those who are, presumably, to occupy the higher positions. No thinking man can doubt the supreme importance of training leaders; it is hardly a debatable question. But in so doing we should not forget that in these days intelligent leadership is useless or at least greatly handicapped without intelligent followers; and our educational methods should take cognizance of *all* kinds of men, keeping in mind that the vast majority of these will always be found in the ranks of the followers.

So there has lately grown up a sentiment that our science teaching is drifting away from the close contact it should have with life and democratic education. We are confronted with the strange charge that our science courses, formerly looked upon by the classical scholar as the very essence of things practical, are no longer practical. We are told that they are neither life itself nor preparation for life. We are told that just as the older educational methods erred in supposing that the repeating of words and the observance of forms produced educated men, so we are likely to mistake the shadow for the substance in expecting to send out men trained in the scientific method and filled with the scientific spirit simply because they have worked over and perhaps memorized certain standard forms of mathematically expressed scientific laws. In other words, we are charged with transferring the error of the older methods to new fields, and the cry has gone forth that science teaching must be again vitalized, that it must be made more practical and brought back close to the industries whence modern science sprung. Most of us will admit freely that there is some truth in these assertions, particularly as regards the failure of our highly developed science courses to take cognizance of the needs of the great mass of men and women who go no further in academic work than the end of the high school course. The majority of them do not engage in callings where expert scientific knowledge is an essential. Yet all should have some scientific training, first to acquire, if possible, the scientific method of attack, because this is the weapon with which we have made ourselves masters of physical things, and second that they may be reasonably intelligent regarding the natural phenomena that surround them on every hand with ever increasing complexity. There is no doubt that high school science can be made more effective for the great mass of the people by making it somewhat less formal, and bringing it closer to the lives of the plain people.

But before we proceed far with our reformation it may be well to define first just what we mean by *practical scientific education.* Do we mean (1) the giving simply of descriptive information and explanations of every-day phenomena; or do we mean (2) the using of these every-day phenomena to interest the student in rediscovering the laws that underlie them; or again do we mean (3) the application of these rediscovered principles, formally expressed, to practical every-day problems in sufficient degree to secure to the student ability to handle the formal mathematical statement of these principles in an easy and confident manner?

A very cursory examination of college and high school curricula will show that all three of these progressive steps are in common use.

I have in mind a certain course given in a certain college, that shall be nameless, that is strictly of the first kind. It is eminently practical and I believe it is as eminently useless as far as mental development is concerned.

This interpretation of practical education is common and the inadequateness of this form of instruction *taken by itself* is so glaring when compared with some of the old and much-maligned classical methods as to make one pause and wonder. Yet there are, as we shall see, places in our educational structure where such courses are not only desirable but necessary. The error comes in assuming that they are sufficient unto themselves as educational tools.

The second interpretation forms the basis of the arguments presented by some of those who would reform our high school science teaching. The claim is made, and with good reason, that the interest of the student is much more readily secured through familiar *visualized* physical phenomena than through the abstract mathematical statements of the underlying principles. Once his attention and interest are secured, it is easy to lead him to investigate and rediscover these laws, thereby acquiring a general knowledge of the phenomena and also the scientific method of approach which should be of use in attacking the many other problems of his life. Or, as Professor Mann[1] has expressed it, the present order of procedure is usually: principle, demonstration, exemplification in laboratory, application; while the newer ideas would make the order: application, problem, solution in the laboratory, principle. Professor Mann's reasoning for this order is based on his definition of the benefits to be derived from the study of physics (and the same argument holds for all other fundamental sciences). These benefits he says are of two kinds; they consist of (1) useful knowledge of physical phenomena; (2) discipline in the methods of acquiring this useful knowledge. No fault can be found with this statement as far as it goes and, as will be shown, there are parts of our educational structure where this form of instruction, like the former one, is not only justifiable but sufficient. The error again is in assuming that this order of procedure forms an educational basis sufficient for all men and all forms of study. Let us see where this reasoning will carry us.

[1] "The Teaching of Physics," p. 213.

As this writer himself points out, knowledge of physical phenomena and discipline in acquiring it may be either *specific* or *general*, and specific knowledge and training acquired by studying some special field becomes more and more useful as it becomes more and more general by being used and interwoven with a wide range of experience. This is true not only of scientific studies, but of all forms of educational effort. Let us then apply this new theory to the teaching of some simple fundamentals such as reading and spelling, where, incidentally, the method of approach advocated is already well developed. By means of the common objects of the child's environment he soon is taught the principles of reading and spelling and may acquire not only much information regarding these objects, but a considerable mental development in attack, with a considerable knowledge of the principles involved in reading and spelling. But he is still a long way from being able to either read or spell even after these principles have been made evident to him. He must now *apply* these principles long and tediously before he can master this fundamental study. This is even more marked in mathematics. Approach through applications, demonstrations and investigation to secure data, and the discovery of the principles involved are not sufficient. To use these principles freely requires long and close application of them, and while this labor may be made more interesting by using practical problems, there is a *quantitative* element that can not be overlooked. This is very clearly instanced in the case of factoring in algebra. Many cases of a similar kind may be cited even when the processes are manual in their character. It is easy, for example, to approach the making of good letters and figures through the making of mechanical drawings of some familiar object that the student is interested in. But even after the student

sees the application and need of good letters and figures, and even after he has had the theory of any good system of lettering carefully expounded, he will never make good characters till he has toilsomely applied that theory many, many times. Again we may awaken the interest of the student in, say, the art of planing wood with a hand plane by showing first the principles of power planing machines and then the construction and principles of hand planes. But he will never master the use of the instrument except through persistent and often toilsome effort, even though that effort be made interesting by application to practical problems. And the general principle is true of all fundamental work, mental or manual, that the student expects to build upon for the future. There is a tremendous difference between knowing a lot about general physical phenomena with the methods of finding the principles involved, and the power to use the formal statements of these principles in attacking other problems. And while, as before stated, it may sometimes be desirable and sufficient to stop at the end of the first or second stage noted above, care must be exercised that this is not done in any subject where the accurate and confident use of the formal principles rediscovered are essential to future progress. Evidently this applies to the teaching of all elementary fundamental subjects, but the dividing line may perhaps be made more clear by studying the problems presented in so-called industrial education, which is very likely to be effected by this new movement.

Aside from inherent ability and general or liberal knowledge the accomplishments that industrial workers must possess are of three kinds: (1) Manual skill; (2) industrial or manufacturing knowledge; (3) scientific knowledge and the ability to *use* it. The first is self-explanatory. The second refers to the knowledge of shop processes and methods of manufacturing and the finance and economics of production. The first two may be partially acquired in schools, but as a general principle their full attainment must be acquired in the atmosphere of the shop or factory. The third refers to the knowledge of the natural scientific laws that may, in general, be acquired from books better than from actual shop work. Now the position which an industrial worker may occupy is governed by the relative amount of these three accomplishments that he may possess. Thus a good tool-maker must possess a certain amount of scientific knowledge and must possess a maximum of manual skill. The shop manager must possess a certain amount of scientific background but must be highly informed regarding manufacturing methods. The engineer must have some manual skill and shop knowledge and must be well grounded in scientific principles and their application. It is important to note that he must not only have a general knowledge of the scientific phenomena on which his work is based, but he must be able to *apply* their formal mathematical expressions freely and accurately. Superficial knowledge is not enough. In his most highly developed form the engineer must pass out of the realm of visualized principles and reason with abstruse, abstract scientific phenomena far removed at times from the practical. The ability to do this requires not only a full knowledge of principles but an ability to use them that can come only from long and persistent practise. And it is to be especially noted that the foundation of this ability must be laid in the school. Time was when a bright man could easily acquire in the shop the scientific background required for any engineering work. The complexity of modern engineering has, however, changed all this and the man who is to rise to any height in the field must in general acquire this scientific background before he enters it. *Men seldom add to their scientific base line after leaving school,* and the height to which they rise along scientific lines is measured almost absolutely by the amount of solid scientific training they take away from the school. This is not dogma, but history, and can be easily verified by any one. It is particularly true of the electrical engineer and similar industrial workers in the higher levels of industry.

But *all* the courses offered to the embryo electrical engineer need not be of the searching character indicated by the above. Thus

his principal work in life may be "buttressed" and made more effective by a course in steam engineering, for instance, that goes no further than the second stage mentioned above. It is sufficient if he knows the *forms* of steam apparatus and the general principles underlying their construction without ever applying these principles to design or investigation. On the other hand, the steam engineer and civil engineer are rounded out and their work made more effective by a course in the forms and characteristics of electrical machinery without going into the rigid application of the fundamental principles involved. It thus appears that we may with good logic stop at either the first or descriptive stage or at the end of the second or experimental stage of a given line of instruction, provided we properly interpret the effect; but for fullest mental development and ability to make practical use of the theory involved the process must be continued through the phase of thorough mathematical application.

What is true of the college is true also of the secondary school. When we have fully developed our secondary school system we shall have several, if not many kinds of such schools. The preparation of the few going to engineering colleges will be conducted more and more along the lines of general or humanistic studies. They will study fewer courses and will study them more thoroughly. For the many going out into the world from the high school we shall have, as before stated, several kinds of schools all with vocational direction and some of them plain trade schools. Each one of these schools will have a central course or courses carried as far as possible through the third stage, and these central courses will be strengthened and buttressed by other practical or scientific courses that will be stopped not later than the end of the second stage. Some of these central courses will be very practical and some more mathematically scientific than we may perhaps imagine. For industry tends to become more scientific and as a consequence more mathematical. If one doubts this he should look carefully into the mathematical work involved in reducing to workable form, Mr. W. F. Taylor's[2] experiments in the very practical study of the laws underlying the cutting of metals. It required high mathematical attainment to solve what might seem at first to be a simple practical problem, and to-day many workmen in this country are doing such extremely practical work as setting the cutting speeds and feeds of machine tools by means of slide-rules the mathematical basis of which is far beyond their conception. And these same general observations and principles will apply throughout the entire range of vocational education. This, I believe, is the true interpretation of this new movement.

There *is* a place for courses much more practical and more attractive to the student than those built solely along mathematical lines. But do not let us delude ourselves that this idea constitutes a complete new educational scheme. In this connection it is well for us to remember the history of some of the educational reform movements we have already witnessed. When we tore away from the old classical form of education it was firmly believed that we could build up an educational edifice that would give as good, if not better results, not only as regards mental development, but as regards general training and outlook on life. It is interesting to note that the engineering colleges, that have benefited by this separation as much if not more than any other form of educational activity, long ago realized that we can not profitably throw away human experience and have already begun to swing back and more and more to build their work on the humanities as a sure foundation. When the broadly elective system was brought forward it was heralded as the final solution of educational problems, but already we have evaluated its influence and adopted it partially, only, in the form of elective *groups* of study. And so this new movement in science teaching can not disregard human experience. No power of concentration and no mental development worth while can ever come about except by hard and unremitting toil. We may

[2] See *Trans. American Society of Mechanical Engineers*, Vol. 28.

sweeten the dose, but to be fully effective the student must swallow it all, including the rigorous drill that can come only from the many applications that must be made before the benefit becomes an integral part of his personality.

And I am not so sure that we may not do some harm by oversweetening the dose. The theory that there is no pleasure in abstract mental effort is in my opinion more or less of a fallacy. There is a certain satisfaction that comes from successful effort, whether the work accomplished be abstract or practical. Students are naturally more interested in practical than in theoretical matters, and a teacher lacking in inspiration can very well help his work by a careful choice of illustrations. But to the student who sits under a teacher whose instruction is illuminated by the "divine spark" all things are interesting, whether they be music or logarithms. Let us not confuse *mechanism* with *inspiration*. Furthermore, it is a good thing for boys and girls to be compelled to do a certain amount of uninteresting if not unpleasant work. The duties of life are not, on the whole, entirely pleasant; and since proficiency in overcoming obstacles is obtained only by overcoming a few, perhaps a little uninteresting work is a good thing, after all. Huxley says, "the best way to learn how to do a thing is by doing something as near like it as possible, but under easier and simpler conditions." There is no royal road to learning; and if the three R's are the basis of our educational methods, so the way of mastering them and attaining the mental heights their mastery leads to lies through the three T's. No high mental development ever has or ever will be accomplished without a liberal application of toil, trouble and tears.

DEXTER S. KIMBALL

January 17, 1913

THE MINING CONGRESS AND EXPOSITION IN PHILADELPHIA

MANUFACTURERS of mining machinery, rescue and first-aid apparatus and safety appliances are to be given an opportunity to display their wares before the mining men of the country at an industrial exposition to be held under the auspices of the American Mining Congress, in Philadelphia, Pa., during the week of October 20.

This exposition, the first of its kind in this country, will be held in conjunction with the annual convention of the Mining Congress. It will be national in scope, the metal mining interests of the west to be as fully represented as the coal mining of the east. There is a tentative plan to have a gold mining camp in full operation with a mill crushing the ore. Horticultural Hall, situated in the heart of the city, has been engaged for the occasion.

While the plans are still in embryo, a number of the leading manufacturers have already been approached and have shown sufficient interest to lead to the belief that all the space will be taken.

A number of the large coal companies that have developed the "safety first" movement at their mines are arranging for space to show the mining men and the public what they are doing in behalf of their men. These companies will send rescue and first-aid crews and there is talk of exhibition drills between the various crews. The U. S. Bureau of Mines will be represented by one of its safety cars and a picked crew of helmet men. The state of Illinois and a number of the anthracite companies may send rescue cars for exhibition purposes.

The convention is the first to include all the mining interests of the country and an attempt is to be made to show the need of a stronger national organization that will represent all phases of the industry. Perhaps the leading topic of the convention will be the new system of mine taxation recently put in operation in some states and being discussed in others at the present time. It is expected that a definite policy toward Alaska from congress will be asked.

The smelter fume problem will be discussed with the hope that an amicable adjustment may be reached soon. California has, at the present time, two commissions considering this problem and Montana, one.

The disposal of debris from placer mining is